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COLEMANITE DEPOSITS NEAR KRAMER JUNCTION, SAN BERNARDINO COUNTY, CALIFORNIA

By James R. Evans[1] and Thomas P. Anderson[1]

PREFACE

Two buried deposits of the calcium borate *colemanite* were discovered in the late 1950's near Kramer Junction, western San Bernardino County. The Sunray Mid-Continent Oil Company deposit is quite small and of very low grade. The Rho deposit now owned by Tenneco Mining, Inc., was estimated by Griswold (1959) to contain 40 million tons of colemanite-bearing shale having an average grade of 14 percent B_2O_3.

A re-examination of data on these deposits was made by the California Division of Mines and Geology in early 1976 because of the growing importance of calcium borate ores. The major known deposits of colemanite and ulexite-probertite occur in Death Valley National Monument, and significant deposits occur in the nearby Ryan area. Congress is considering [July 1976] legislation to limit or prohibit mining in the Monument. Therefore deposits outside of the Monument have come under close scrutiny and re-evaluation. To aid interested parties, the California Division of Mines and Geology is publishing information on newly discovered, as well as previously known, colemanite and ulexite-probertite deposits.

The colemanite deposits near Kramer Junction are estimated herein to contain 12 million tons of 17 percent B_2O_3, 24 million tons of 14 percent B_2O_3, 47 million tons of 9 percent B_2O_3, and 11 million tons of 5 percent B_2O_3. There are major problems associated with these deposits and the mining thereof that may preclude their development for the foreseeable future.

RHO COLEMANITE DEPOSIT

Discovery

The Rho colemanite deposits were discovered by the U.S. Geological Survey in 1957 during their deep-drilling program in the Kramer area 30 miles west of Barstow. Five test holes were drilled where geophysical and geologic studies indicated that thick sections of Quaternary and Tertiary rocks existed under the desert surface. It was thought that these rocks could be similar to those that contain the large sodium borate deposit at Boron, Kern County, 7 miles west. The existence of colemanite was verified when diamond drill hole Four Corners No. 5, 1½ miles north of Kramer Junction in SE¼ sec. 30, T11N, R6W, penetrated beds of the mineral (Benda and others, 1960).

The discovery led to further drilling by several companies in the Kramer area. During 1958–59, Kern County Land Company drilled 28 exploration holes in secs. 29, 30, 31, and 32, T11N, R6W. Drilling was mostly on ten lode claims (now patented) filed by Kern County Land Company in SE¼ sec. 30 (Rho A) and in SW¼ sec. 29 (Rho B owned by the Hinkley Realty Company, Hinkley, California) (figure 1).

Kern County Land Company was purchased in 1967 by Tenneco Mining, Inc. The records, assays, and other data were provided to the California Division of Mines and Geology in March 1976 for an independent analysis. This material, discussions with Tenneco's technical staff, and information published by the U.S. Geological Survey provide the basis for this report.

General Geology

The Rho deposits are near the middle of a sequence of at least 2,500 feet of greenish fissile silty claystone and silty sandstone lakebeds assigned to the upper part of the Tropico Group of Miocene(?) age. Dibblee (1967, p. 126) indicates that the colemanite-bearing beds are probably correlative with part or all of the 320-foot thick unit that contains the sodium borate deposit at Boron. Overlying the Tropico lakebeds is 700 feet of younger alluvium. Underlying the lakebeds are Oligocene(?) to Miocene(?) fanglomerate and sandstone of the lower part of the Tropico Group (figure 1). The Tropico Group is warped into a broad syncline, the axis of which trends generally east. The Rho deposits are on the flattish south limb of the syncline.

Geologic sections plotted from the exploratory drill hole data show two vertically separated, discontinuous colemanite-bearing zones that occur in an interval 475 feet thick and from 775 feet to 1,250 feet below the surface. Both zones are parallel to bedding in the lakebeds which generally dips southeast from a few to 15 degrees. Generally the two zones are separated by 25 feet to 50 feet of shale and sandstone (figure 2).

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[1] Geologist, California Division of Mines and Geology

Mineralogy and Chemistry

Cores of silty claystone and silty sandstone which appear to be typical of the upper part of the Tropico Group in this area were examined by the authors. They were composed mostly of montmorillonite (swelling clay) with some quartz grains. Feldspar grains and biotite flakes are common but make up only a few to several percent of the samples. Analcime and heulandite were reported in cores from the borate-bearing zones in diamond drill hole Four Corners No. 5 (Benda and others, 1960, p. 330). Hydrous iron oxides are common as discontinuous coatings along bedding planes and locally in nodules of irregular shape about 1 inch in maximum dimension. Mild effervescence in dilute HCl indicates the presence of calcite in nearly all the samples examined.

Colemanite crystals from silt size to ¼ inch or more in longest dimension are disseminated through the cores from the colemanite-bearing zones and in seamlets and beds from a fraction of an inch to as much as 4 inches thick. Most seamlets and beds observed in the cores, however, are about ¼ inch thick. Analyses of colemanite-bearing zones from all 28 drill holes show a range of B_2O_3 content from 0.25 to 27 percent.

Realgar and orpiment, sulfides of arsenic, occur as discontinuous coatings and patches on bedding planes and as veinlets and inclusions in colemanite grains (table 1).

Table 1. Analyses of 30' of core from drill hole 105-10 (SW¼ sec. 29, T11N, R6W).

Core interval (feet)	B_2O_3 (%)	CaO (%)	Na_2O (%)	As_2O_3 (%)	As (ppm)
1106-1111	8.00	8.10	0.97	0.188	1425
1111-1116	7.97	6.60	0.97	0.145	1099
1116-1121	9.31	8.30	0.97	0.110	834
1146-1151	13.64	9.70	0.84	0.123	932
1151-1156	13.22	8.60	0.84	0.156	1182
1156-1160	11.12	7.20	0.97	0.138	1046

*Arsenic analyses by Atlas Chemical Testing Laboratories, Las Vegas, Nevada. Other analyses by Tenneco Mining, April 1976.

Realgar and orpiment were noted by Kern County Land Company from visual examination in core from 20 diamond drill holes. The Company was concerned about the arsenic content, as more than 287 parts per million (ppm) arsenic was not acceptable to the glassware industry. Therefore, Kern County Land Company sent a 243.5-pound composite of five samples of drill cores from colemanite zones to the Colorado School of Mines Research Foundation for analysis (Jameson, 1965). The raw sample contained 14.3 percent B_2O_3 and 0.14 percent (1400 ppm) arsenic.

Because commercial use of colemanite hinges on greatly reducing the arsenic content, washing and calcining tests were conducted as possible methods to accomplish this. After the sample was washed, scrubbed, screened, and decanted, the arsenic content was reduced to 0.104 percent (1040 ppm), and the B_2O_3 content to 42.6 percent (recovery of B_2O_3 was 61.5 percent). After the washed and screened sample was calcined, it contained 0.172 percent (1720 ppm) arsenic. During calcining, surface moisture and water of hydration from the colemanite were lost, and the sulfides of arsenic were converted to the oxide of arsenic. The calcined product assayed 54.1 percent B_2O_3 (recovery of B_2O_3 was 49.7 percent).

Analyses of some typical samples selected by the authors is given in table 1. The arsenic content of the samples was uniformly high.

Tonnage and Grade

The Rho A deposit is in a block 3,000 feet by 2,400 feet, and the Rho B deposit is in a block 2,300 feet by 1,400 feet (figure 1). The upper and lower zones occur in each deposit. Drilling was more closely spaced in Rho A and hence provided more reliable information for tonnage and grade calculations (tables 2 and 3). Two geologic sections were prepared to assist in the calculation (figure 2). It cannot be overemphasized that these data were derived from exploratory drill holes and that more drilling is needed to better define the extent of the two zones in each deposit and to determine more reliable tonnage and grade figures.

Our rough estimates made from unpublished data show that the lower zones of the Rho A and B deposits contain 47 million tons of colemanite-bearing material containing 9 percent B_2O_3; that the upper zone of the Rho A deposit contains 24 million tons averaging 14 percent B_2O_3; that the subzone of the upper zone of the Rho A deposit contains 12 million tons of 17 percent B_2O_3; and that the upper zone of the Rho B deposit contains 11 million tons averaging 5 percent B_2O_3.

While these tonnages are very high the grade is below currently minable grade. For example, Tenneco Mining is presently mining arsenic-free colemanite-bearing material containing about 20 percent B_2O_3 at their Boraxo mine in Death Valley.

Potential Mining Methods

Development and mining of the deep Rho deposits would present several major problems. At present there is insufficient data on the general nature and strength of the lakebeds enclosing the colemanite-bearing zones to plan the most feasible mining method. At least one exploration shaft and several exploration drifts would have to be sunk before a proper and safe mining method could be decided upon, and costs evaluated.

Some simple experiments indicate the wall rocks would become weak if they got wet. Core samples placed in water for one hour completely dissociated by swelling and forming an irregularly shaped sticky blob, indicating that the montmorillonite-rich wall rocks might "flow" on addition of water. The upper ground water surface in the Kramer Junction area is 100 feet below the surface; elevation of the lower surface was not recorded on the drilling logs.

SUNRAY MID-CONTINENT OIL COMPANY DEPOSIT

The Sunray Mid-Continent Oil Company deposit was discovered in 1958 through drilling by that company in S½ sec. 13 in T11N, R7W, about 2 miles northwest of the Rho deposits (figure 1). Colemanite-bearing shale was found in three core holes near the middle of sec. 13, but four other holes drilled to the west and north in sec. 13 did not penetrate colemanite-bearing shale (table 2; Dibblee, 1967, p. 127). Dibblee reported that the seven core holes ranged in depth from 538 to 575 feet and that the shale below the alluvial debris presumably dips southward from 20° in the southerly holes to 55° in the northerly holes. The depth to

Table 2. Exploratory drill holes, east Kramer colemanite area (modified from Dibblee, 1967, p. 142-146).

Hole no.	Location (feet)	Year drilled	Collar elev. (feet)	Geology		
				Footage and depth (feet)	Symbol on fig. 1	Lithology
SUNRAY MID-CONTINENT OIL COMPANY DEPOSIT*						
54	2,010' north, 2,165' east of SW cor. sec. 13	1958	2,580'	0-150'	Qa	---
				150-484'	Ttu	Clay shale; dips 20°.
				484-575'	Ttu	Clay shale; contains howlite above 535', colemanite below 535'; dips 22°.
52	2,000' north, 2,480 west of SE cor. sec. 13	1958	2,576'	0-250'	Qa	---
				250-455'	Ttu	Clay shale; dips 20°.
				455-556'	Ttu	Clay shale; contains howlite above 520', colemanite below 520'; dips 20-22°.
55	1,400' north, 1,880' west of SW cor. sec. 13	1958	2,570'	0-230'	Qa	---
				230-341'	Ttu	Sandstone and clay shale interbedded.
				341-386'	Ttu	Clay shale and white ash.
				386-458'	Ttu	Clay shale; contains colemanite.
				458-575'	?	---
RHO DEPOSIT**						
105-12	1,000' north, 500' east of SW cor. sec. 29	1958	2,470'	0-857'	Qa	---
				857-1,226'	Ttu	Clay shale, thin beds of sandstone below 1,160'; contains colemanite and realgar (0.22-14.67% B_2O_3 from 919' to 1024'; 0.36-26.25% B_2O_3 from 1054' to 1225'); dips 3-15°.
				1,226-1,296	Ttu	Clay shale, minor amount of sandstone; dips 5°-20°.
115-12 and 115-12A	1,000' north, 1,500' east of SW cor. sec. 29	1958	2,464'	0-863'	Qa	---
				863-1,146'	Ttu	Clay shale, thin sandstone beds; contains colemanite and realgar (0.40-14.64% B_2O_3 from 912' to 1007'; 0.54-18.90% B_2O_3 from 1034' to 1133').
				1,146-1,207'	Ttu	Clay shale and sandstone.
125-11	500' north, 2,500' east of SW cor. sec. 29	1958	2,461'	0-580'	Qa	---
				580-812'	Ttu	Clay shale; contains colemanite (1.59-15.54% B_2O_3 from 705' to 799'); dips 5-10°.
				812-917'	Ttu	Sandstone and clay shale.
70-14	2,000' north 2,420' east of SW cor. sec. 30	1957	2,486'	0-1,001'	Qa	---
				1,001-1,203'	Ttu	Clay shale, thin sandstone beds below 1,097'; contains colemanite (1.81-10.86% B_2O_3 from 1011' to 1050'; 1.81-7.97% B_2O_3 from 1,063' to 1,083'); dips 5-10°.

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Table 2. Exploratory drill holes, east Kramer colemanite area (modified from Dibblee, 1967, p. 142-146), continued.

Hole no.	Location (feet)	Year drilled	Collar elev. (feet)	Geology		
				Footage and depth (feet)	Symbol on fig. 1	Lithology
RHO 15	2,500' north, 2,000' west of SE cor. sec. 30	1957	2,486'	0-915'	Qa	---
				915-1,077'	Ttu	Clay shale, few thin sandstone beds; contains colemanite (0.90-14.41% B_2O_3 from 979' to 1,040'); dips 5-10°.
				1,077-1,155'	Ttu	Sandstone, minor amount of clay shale.
RHO 16	2,000' north, 1,800' west of SE cor. sec. 30	1957	2,482'	0-780'	Qa	---
				780-1,012'	Ttu	Clay shale; contains colemanite (1.44-25.41% B_2O_3 from 809' to 891'; 6.59-14.60% B_2O_3 from 937' to 992'); dips 5-10°.
				1,012-1,028'	Ttu	Sandstone.
RHO 17	1,500' north, 2,000' west of SE cor. sec. 30	1957	2,479'	0-715'	Qa	---
				715-940'	Ttu	Clay shale; contains colemanite (0.36-18.74% B_2O_3 from 789' to 844'; 4.51-13.15% B_2O_3 from 864' to 912'); dips 2-5°.
				940-971'	Ttu	Clay shale and sandstone.
RHO 6	2,580' north, 470' west of SE cor. sec. 30	1957	2,482'	0-760'	Qa	---
				760-890'	Ttu	Clay shale, sandstone, and conglomerate at 784-831'; dips 25° at 781'.
				890-910		Sandstone, clay shale, conglomerate; dips 15°.
RHO 7	2,200' north, 470' west of SE cor. sec. 30	1957	2,478'	0-730'	Qa	---
				730-857'	Ttu	Clay shale, thin sandstone beds below 822'; contains colemanite (3.96-16.04% B_2O_3 from 783' to 818'); dips 10-20°.
				857-935'	Ttu	Sandstone, minor amount of clay shale; dips 20°.
RHO 8	1,600' north, 1,050' west of SE cor. sec. 30	1957	2,477'	0-720'	Qa	---
				720-954'	Ttu	Clay shale; contains colemanite (0.36-23.07% B_2O_3 from 791' to 842'; 1.80-19.82% B_2O_3 from 870' to 958'); dips 10-20°.
				954-985'	Ttu	Sandstone, minor amount of clay shale; dips 20°.
RHO 18	1,000' north, 2,400' west of SE cor. sec. 30	1957	2,478'	0-660'	Qa	---
				660-914'	Ttu	Clay shale, few sandstone beds; contains colemanite 1.26-22.89% B_2O_3 from 744' to 802'; 0.72-12.43% B_2O_3 from 828' to 907'); dips 0-45°.
				914-927'	Ttu	Sandstone, minor amount of clay shale; dips 5-10°.
RHO 19	510' north, 670' west of SE cor. sec. 30	1957	2,470'	0-725'	Qa	---
				725-1,069'	Ttu	Clay shale; contains colemanite (13.68-21.26% B_2O_3 from 990' to 1026'); dips 10-20°.
				1,069-1,148'	Ttu	Sandstone, minor amount of clay shale; dips 10-20°.

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Table 2. Exploratory drill holes, east Kramer colemanite area (modified from Dibblee, 1967, p. 142-146), continued.

Hole no.	Location (feet)	Year drilled	Collar elev. (feet)	Geology		
				Footage and depth (feet)	Symbol on fig. 1	Lithology
RHO 9	1,050' north, 870' west of SE cor. sec. 30	1957	2,474'	0-715'	Qa	---
				715-982'	Ttu	Clay shale; contains colemanite (8.65-17.48% B_2O_3 from 855' to 871'; 2.16-18.20% B_2O_3 from 894' to 982'); dips 6°.
				982-999'	Ttu	Sandstone and clay shale.
RHO 20	450' north, 2,000' west of SE cor. sec. 30	1957	2,474'	0-720'	Qa	---
				720-965'	Ttu	Clay shale; contains colemanite (6.31-18.56% B_2O_3 from 814' to 854'; 8.65-16.40% B_2O_3 from 900' to 946'); dips 20-30°.
Four Corners #5	60' north, 410' west of SE cor. sec. 30	1957	2,462'	0-700'	Qa	---
				700-1,155'	Ttu	Clay shale; contains colemanite (1.82-27.06% B_2O_3 from 1,051' to 1,145'); dips 0-5°.
				1,155-1,360'	Ttu	Clay shale, minor amount of sandstone; contains colemanite (8.99-17.72% B_2O_3 from 1,241' to 1,252').
				1,360-1,604'	Ttl?	Granitic sandstone and conglomerate.
95-9	500' south, 500' west of NE cor. sec. 31	1958	2,461'	0-590'	Qa	---
				590-1,091'	Ttu	Clay shale, some sandstone; contains colemanite (trace of B_2O_3 from 932' to 939'; 4.99-8.46% B_2O_3 from 986' to 993'; 3.65-13.01% B_2O_3 from 1,044' to 1,076'); dips 7-25°.
				1,091-1,157'	Ttu	Sandstone, minor amount of clay shale.
105-10	500' east of NW cor. sec. 32	1957	2,465'	0-738'	Qa	---
				738-1,236'	Ttu	Clay shale, minor amount of sandstone below 1,162'; contains colemanite (0.54-14.30% B_2O_3 from 1,056' to 1,231); dips 5-10°.
				1,236-1,356'	Ttu	Clay shale; dips 5-10°.
115-10	1,500' east of NW cor. sec. 32	1958	2,463'	0-750'	Qa	---
				750-1,193'	Ttu	Clay shale; contains colemanite and orpiment (2.53-6.98% B_2O_3 from 908' to 933'; 5.79-9.05% from 992' to 1,020'; 2.35-14.30% from 1,040' to 1,175'); dips 10°.
				1,193-1,270'	Ttu	Sandstone and clay shale; dips 3-21°.
125-9	500' south, 2,500' east of NW cor. sec. 32	1958	2,453'	0-712'	Qa	---
				712-1,003'	Ttu	Clay shale, minor amount of sandstone; contains colemanite (4.84-7.26% B_2O_3 from 822' to 838'); sparse howlite at 960-1,003'; dips 5-10°.
				1,003-1,085'	Ttu	Sandstone and clay shale.

*Source of data: Sunray Mid-Continent Oil Company.

**Source of data: Tenneco Mining, Inc., and Four Corners #5--Benda and others (1960). Four Corners #5 drilled by U.S. Geological Survey; all others drilled by Kern County Land Company.

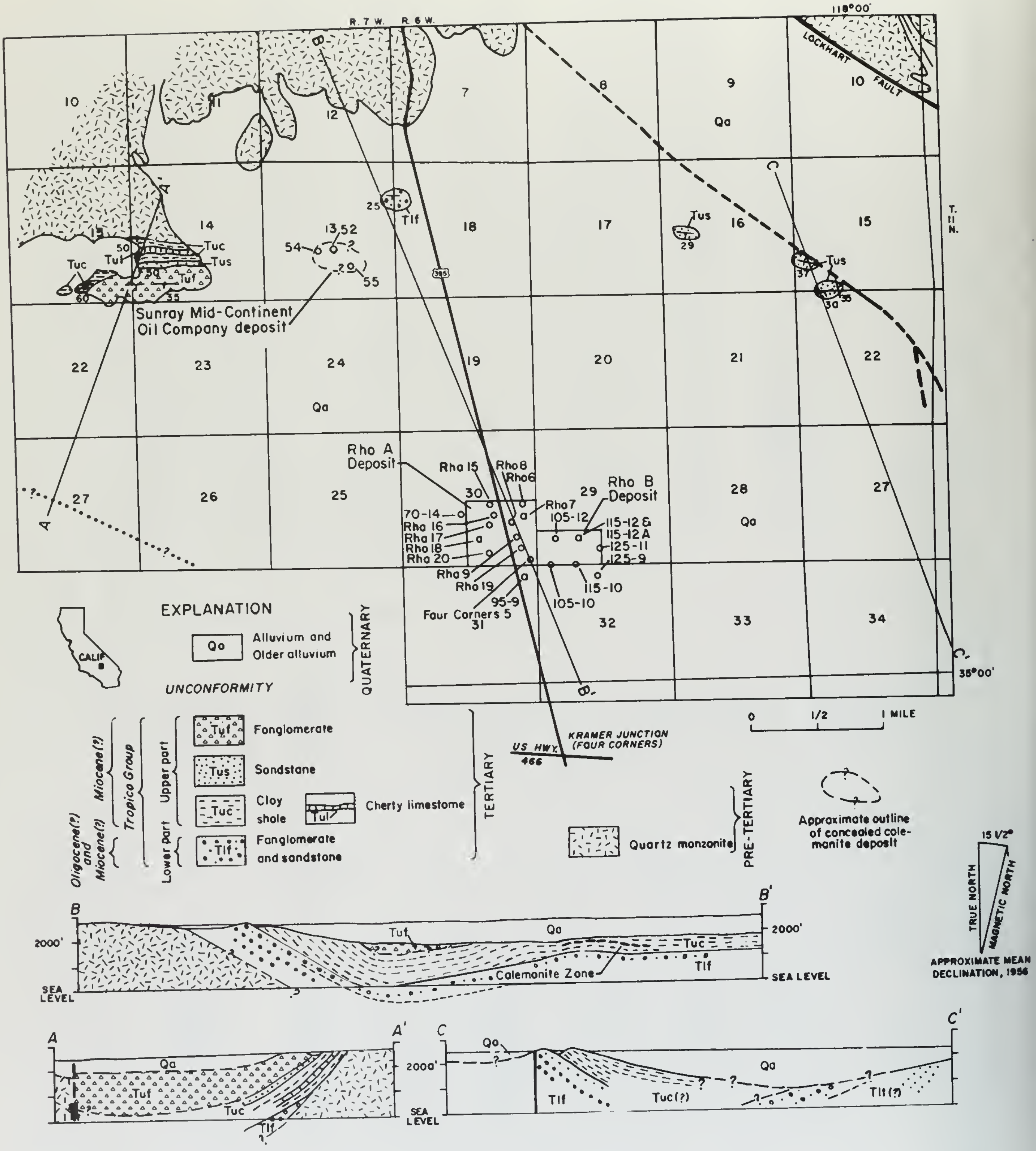

Figure 1. Geologic map and sections of east Kramer colemanite area. *Modified from Dibblee, 1967, p. 78.*

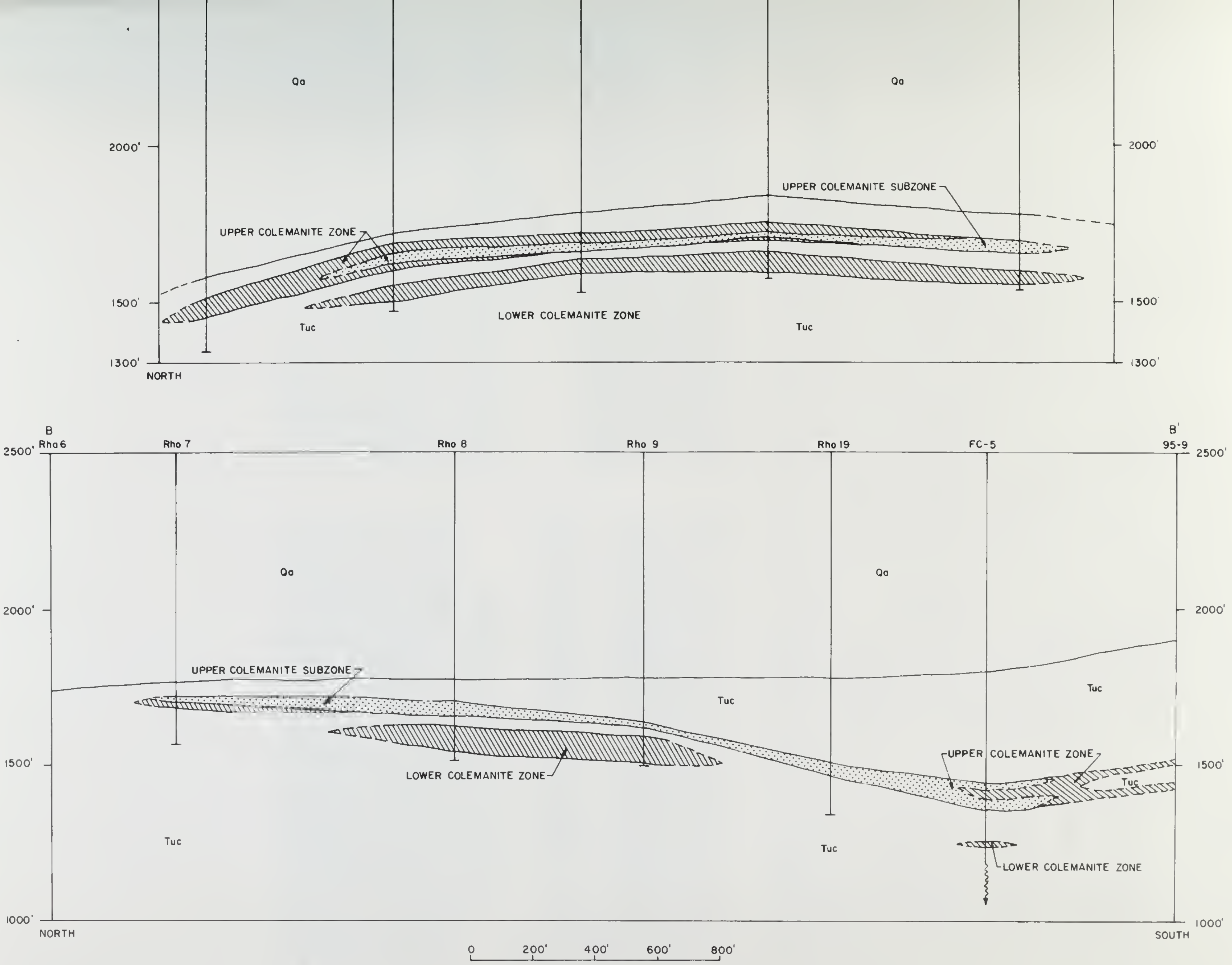

Figure 2. Geologic sections through the Rho A deposit.

Table 3. Data on Rho colemanite deposits.

	RHO A DEPOSIT		RHO B DEPOSIT	
	Upper zone (including subzone)*	Lower zone	Upper zone	Lower zone
Depth from surface at middle of zone	775-1100 feet (790-1100 feet)*	875-1250 feet	715-975 feet	775-1150 feet
Range of thickness	10-94 feet (10-40 feet)*	0-93 feet	0-95 feet	45-175 feet
Average thickness	50 feet (24.6 feet)*	55 feet	50 feet	125 feet
Area of deposit	7,200,000 sq. ft.	5,400,000 sq. ft.	3,220,000 sq. ft.	3,220,000 sq. ft.
Estimated colemanite-bearing material	24,000,000 tons** (12,000,000 tons)*	20,000,000 tons**	11,000,000 tons**	27,000,000 tons**
Approximate grade	14% B_2O_3 (17% B_2O_3)*	9% B_2O_3	5% B_2O_3	9% B_2O_3

*Over-all tonnage for upper zone includes tonnage for subzone; the subzone was figured separately to show the smaller tonnage of 17% B_2O_3.

**15 cubic feet per ton; in-the-ground tonnages that do not reflect recoverable material.

the top of the colemanite-bearing shale was reported to range from 458 to 538 feet; and the thickness of the colemanite-bearing layers from 40 to 98 feet, but the base was not reached. Dibblee (1967, p. 127) also quoted R.N. Maynard, Sunray Mid-Continent Oil Company geologist, that the average grade of the colemanite-bearing shale is about 3.7 percent B_2O_3; tonnage was not given.

The meager information that is available about this deposit indicates it is of presently unminable grade and undetermined tonnage.

SUMMARY AND CONCLUSIONS

Extensive low-grade colemanite-bearing silty claystone and silty sandstone zones known as the Rho deposit occur in the Tertiary Tropico Group in the Kramer Junction area 775 feet to 1,250 feet below the surface. Two distinct colemanite-bearing zones exist, separated by 25 feet to 50 feet of claystone and sandstone; each colemanite zone ranges from 0 to 175 feet thick. The low grade of the zones, their depth below the ground surface, their varied thickness, technical and economic uncertainties of development, mining, and processing to remove arsenic, and recovery rate on processing and calcining would be major concerns in any consideration to mine the deposits.

Another occurrence of colemanite-bearing shale, known as the Sunray Mid-Continent Oil Company deposit, was discovered by drilling, 2 miles northeast of the Rho deposit. The deposit is 40 to 98 feet thick, buried beneath 458 to 538 feet of alluvial debris. It is of presently unminable grade and undetermined tonnage.

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